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ABSTRACT

This third in a series of six modules for a course titled Civil/Structural Inspection deals with concrete component materials and discusses their properties, methods of handling and storage, selection, uniformity, and methods of acceptance. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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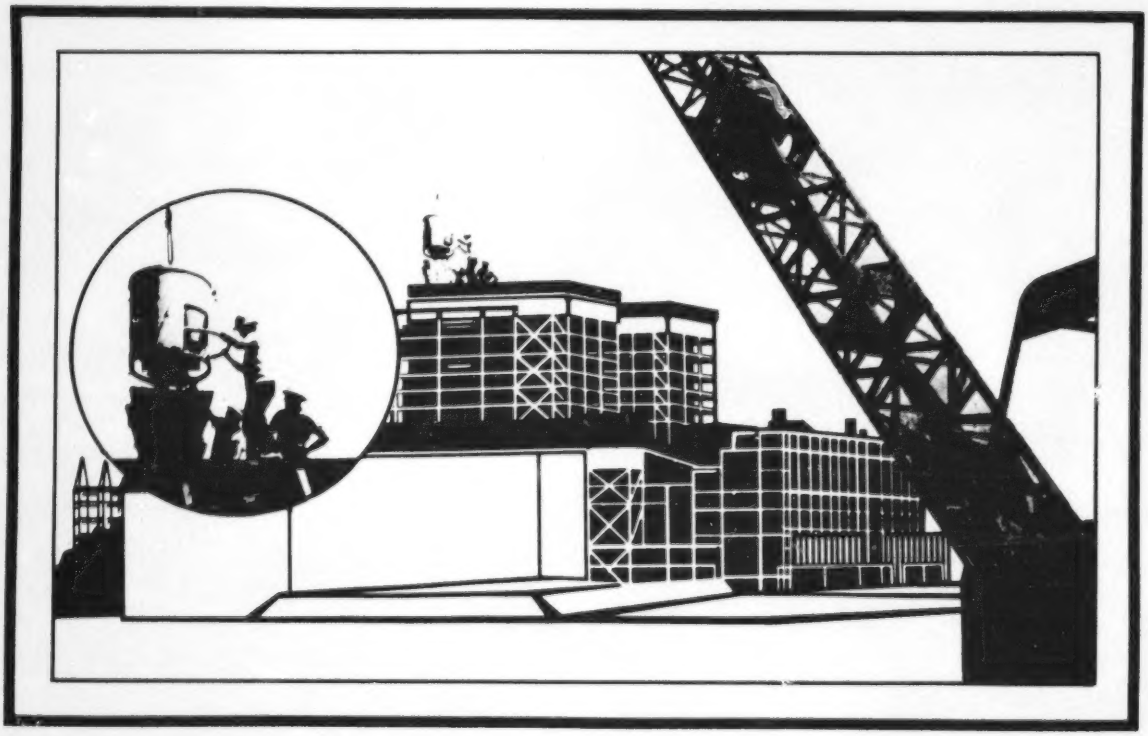
NUCLEAR TECHNOLOGY

COURSE 29 CIVIL/STRUCTURAL INSPECTION

MODULE 29-3 Concrete Materials



CE 024 273

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

Module 29-1 Inspection of Construction Operations

Module 29-2 Structural Steel Materials, Installation and Inspection

Module 29-3 Concrete Materials

Module 29-4 Concrete Preparation, Production, Placement and Finishing

Module 29-5 Concrete Testing and Inspection

Module 29-6 Prestressed Concrete Materials, Fabrication and Inspection

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This module was prepared for General Physics Corporation by Richard Groseclose, General Physics Corporation.

GENERAL PHYSICS CORPORATION

1979

INTRODUCTION

Concrete is one of the most important and widely used construction materials. In its plastic, unhardened state, it can be handled and transported in many ways, such as by trucks, conveyors, pumps and various types of buckets. In its hardened state, it attains strength and durability which are dependent upon such factors as the type, quality and uniformity of component materials, the proportions of component materials, the thoroughness with which they are combined, and the transportation, placement and curing of the concrete.

This module deals with concrete component materials and discusses their properties, methods of handling and storage, selection, uniformity and methods of acceptance.

The information presented in this module reflects general construction practices and is designed to acquaint the trainee with the concrete materials used in the construction of nuclear and fossil power generating plants and similar heavy construction projects.

Supplemental information and reference materials may be obtained from the following sources:

American Concrete Institute (ACI)
American Society for Testing and Materials (ASTM)
National Ready Mixed Concrete Association (NRMCA)
Concrete Reinforcing Steel Institute (CRSI)

MODULE PREREQUISITES

The student/trainee should have prior training or experience on inspections of construction operations. Completion of Nuclear Technology, Module 29-1, satisfies this prerequisite.

OBJECTIVES

Upon completion of this module, the student/trainee can:

1. Identify the three basic components of concrete and describe typical characteristics of each.
2. Associate types of cement with the major characteristics of each type.
3. Describe proper handling and storage practices for cements, aggregates, admixtures, and reinforcing steels.
4. Describe the effect on concrete strength by variations in water quantity, cement quality and aggregate quality.
5. Generally describe the measurement of sizes of aggregates including "fineness modulus."
6. Describe the function of reinforcing steel and its identity marking scheme.
7. Name at least two chemical reactions which aggregate may cause and describe the results in terms of concrete quality.
8. Determine receptability of cements, aggregates, and reinforcing steel when given test results and material specification requirements.

SUBJECT MATTER

COMPONENT MATERIALS OF CONCRETE

Concrete is a mixture of cement, aggregates, water, and sometimes additives or admixtures which impart special characteristics to the concrete such as to accelerate set, retard set, improve workability or reduce the mixing water requirement. Concrete also contains some amount of entrapped air, and may contain purposely entrained air, which produces a more plastic mixture which is easier to place, and more resistant to freezing and thawing.

The selection of concrete proportions involves a balance between economy and requirements for strength and placeability. In general, the mixture consists of one part of cement, 1 1/2 to 2 1/2 parts of fine aggregate (such as sand), 3 to 5 parts of coarse aggregate (such as gravel or crushed stone), and clean water.

Concrete is strong in compression and shear but weak in tension. Compressive strength varies from about 2,000 to 6,000 lbs. per square inch, depending on the proportions. The mixture is plastic and, under normal conditions, will set up firm in a few hours (known as initial set) and attain full rated strength in about 28 days or less.

Reinforced concrete is concrete in which steel, usually in the form of deformed bars or welded wire mesh, is embedded so that the two materials act together in resisting forces. The combination uses the best properties of each material, namely the crush resistance or compressive strength of the concrete, and the pull resistance or tensile strength of the steel. The adhesion of the concrete to the surface of the bars, plus the resistance provided by the bar deformations or lugs, keeps the bars from slipping through the concrete. This gripping of the bars by the concrete is known as bond and makes the two materials act as one.

The selection of the component materials of concrete is made on the basis of availability, cost and characteristics which are required for the particular mix. The following describes the different types of materials and their characteristics.

Cements

The strength of any concrete mixture is directly related to the strength-producing properties of the cement used. The cements most used in the construction industry are portland cements, Types I, II and III. These cements are generally used as follows:

Type I: Used in general concrete construction where the special properties specified for the other types are not required.

Type II: Used in general concrete construction where moderate sulfate resistance or moderate heat of hydration is required.

Type III: Used where high early strength is required.

Other portland cements not generally on the market are produced on order for special purposes:

Type IV: Used when a low neat of hydration is required.

Type V: Used when high sulfate resistance is required.

Portland cement is a hydraulic cement (i.e., a cemetitious material which reacts with water and hardens) produced by proportioning and mixing lime, alumina and silica; burning the mixture to form clinkers; and pulverizing the clinker to form the cement.

Air-entraining portland cements are produced to increase the amount of air held by the mortar or concrete made from the cement. These cements contain small amounts of air-entraining chemicals which are incorporated by intergrinding them with the clinker during manufacture. The additional air held in the resulting concrete improves the workability of the concrete and increases the resistance to freezing and thawing. The strength of air-entrained concrete, however, is usually less than that obtained with untreated cement. Air-entraining portland cements are produced in three of the types listed above, and are designated with the suffix "A", e.g., Type IA, Type IIA and Type IIIA.

Two blended cements have also been standardized by the industry and are available in areas where the materials are available economically. These cements are portland blast furnace slag cement, Type IS, and portland pozzolan cement, Type IP. For each of these there is a corresponding air entraining cement, Type ISA or Type IPA.

Portland blast furnace slag cement consists of a mixture of portland cement clinker and a proportion of 25-65 percent blast furnace slag material.

Portland pozzolan cement consists of an interground mixture of portland cement clinker and a proportion of 15-20 percent fine pozzolan material. The pozzolanic material used is a siliceous or aluminous material in the form of fly-ash, volcanic ash, or heat-treated diatomaceous earth.

The strength characteristics of the portland blast furnace slag cement are essentially the same as for regular portland cements, but the portland pozzolan cements produce significantly lower strengths.

Table 29-3-1 summarizes the minimum compressive strength requirements for the different portland and blended cements, as adopted by the construction industry. It should be noted that the air-entraining cements in all categories have significantly lower strength requirements than for the companion non-air-entraining types.

Table 29-3-1. Minimum Compressive Strength Requirements of Mortar for Different Portland and Blended Cements

Type of Cement	ASTM Specification Designation	Compressive Strength of 2 in Cubes, psi			
		1 day	3 days	7 days	28 days
Non-air-entraining					
I	C 150	----	1200	2100	3500
II	C 150	----	1000	1800	3500
III	C 150	1700	3000	----	----
IV	C 150	----	----	800	1500
V	C 150	----	----	1500	3000
IS	C 205	----	1200	2100	3500
IS(M)	C 205	----	1000	1800	3500
IP	C 340	----	----	1500	3000
Air-entraining					
IA	C 175	----	900	1500	2800
IIA	C 175	----	750	1400	2800
IIIA	C 175	1300	2500	----	----
ISA	C 205	----	900	1500	2800
ISA(MS)	C 205	----	750	1400	2800
IPA	C 340	----	----	1250	2500

Aggregates

Aggregates, known as mineral aggregates, constitute about 70 to 80 percent of the concrete mixture. Conventional aggregates include sand, gravel, crushed stone and blast furnace slag. In addition to these, a variety of lightweight aggregates are used for some applications.

Aggregates are inert filler materials used to make the concrete or mortar more economical and to minimize the shrinkage which is characteristic of most cements.

The principal characteristics considered in selecting aggregates are soundness and durability, hardness and strength, deleterious substances, and size and grading. Soundness and durability rank first among these, especially for concrete exposed to weather. If the aggregate particles disintegrate, the concrete disintegrates.

Aggregates generally are divided into two classes, coarse aggregates and fine aggregates. Coarse aggregate is usually gravel or crushed stone and fine aggregate is usually sand; when sand is not available, fine aggregate is made by crushing rock. Crushed, air-cooled blast furnace slag is sometimes used for fine or coarse aggregate. Lightweight aggregates include cinders and coke "breeze" or residue.

Hardness and strength are important characteristics of coarse aggregates, while grading, soundness and freedom from impurities are particularly important for fine aggregates. The fine particles in the concrete mixture separate the coarse particles and fill the voids between them, minimizing the amount of cement required and yielding a workable mixture.

Aggregate quality is frequently rated by resistance to abrasion, in addition to hardness and strength. Small and large coarse aggregates are tested for this quality with the Los Angeles Abrasion Test (ASTM C131 and ASTM C535). Test results are reported as percentage of wear (or percentage of material abraded away).

Deleterious substances in aggregates usually include clay lumps, coated particles, shale, coal, alkalies, laminated pieces, clay and silt, and organic matter. Concrete strength and durability are affected if these materials are present in any appreciable quantity in the aggregate material.

Aggregates, then, should consist of clean, hard, strong and durable particles which are not coated with dust, clay, silt, or other substances. Aggregates are screened to obtain the desired gradings and washed to remove objectionable impurities.

The sizes of coarse aggregates selected usually depend upon the character of the work. As a rule-of-thumb, the size should not exceed one-fifth the width or thickness of the member in which it is being placed, or three-fourths the clear space between reinforcing bars. A maximum size of 3" for use in any case is frequently specified.

Fine aggregates are generally considered to be all those which pass a sieve with 1/4" square openings. The ASTM standard C125 defines fine aggregate as aggregate (1) passing the 3/8 in. (9.5 mm) sieve and almost entirely passing the No. 4 (4.75 mm) sieve and predominantly retained on the No. 200 (75 μm) sieve, or (2) that portion passing the No. 4 (4.75 mm) sieve and retained on the No. 200 (75 μm) sieve.

The amount of fines, or small particles, in the fine aggregate is a significant factor in proportioning concrete. Samples of fine aggregates are tested by sifting through a series of specified, progressively smaller sieves, and measuring the amounts of material retained on each sieve. An empirical factor, the fineness modulus, is obtained by adding the total percentages of the sample aggregate retained on the sieves and dividing the total by 100. Typical specifications for fine aggregates require that the fineness modulus be within the limits of 2.3 to 3.1.

Water

The water used in concrete or mortar should be clean and practically free from acids, alkalies, salts and organic substances. Excessive quantities of any of these

materials may adversely affect the time and rate of set and strength development. Water that is fit to drink may generally be regarded as acceptable for use in mixing concrete.

Admixtures

Admixtures are materials other than water, aggregates, and cement that are used as ingredients of concrete and are added to each batch immediately before or during its mixing, to impart special properties to the concrete.

Admixtures commonly used include chemical additives; pozzolans such as fly ash and volcanic ash; minerals such as ground quartz, limestone, or talc; coloring agents or pigments; fungicidal, germicidal, or pesticidal agents; dampproofing agents; permeability-reducing agents; and corrosion-inhibiting agents.

Certain chemical admixtures have been classified by ASTM and are defined in terms of function in standard C494 as follows:

Type A - water-reducing admixtures
Type B - retarding admixtures
Type C - accelerating admixtures
Type D - water-reducing and retarding admixtures
Type E - water-reducing and accelerating admixtures

Calcium chloride is a widely used admixture for accelerating set and obtaining high early strength. It is frequently used in cold weather concreting operations.

Many materials are capable of functioning as air-entraining admixtures and are used to enhance resistance to frost action, workability and watertightness of concrete. Some of the materials used are: (1) salts of wood resins, (2) some synthetic detergents, (3) salts of sulfonated

lignin, (4) salts of petroleum acids, (5) salts of proteinaceous materials, (6) fatty and resinous acids and their salts, and (7) organic salts of sulfonated hydrocarbons.

Admixtures of finely divided minerals or pozzolans can be used to produce a variety of effects in concrete. These materials can be used to increase workability of the concrete without an increase in water content, to increase strength, and to reduce permeability. The properties of the specific admixture must be evaluated with the characteristics of the concrete mixture in which it is to be used, however, because some combinations of these materials produce a degradation of desired qualities.

Reinforcing Steel

Concrete has a low tensile strength and must be reinforced for most structural applications. The usual types of reinforcement are steel rods or bars, and welded wire fabric.

The standard type of reinforcing steel bar is the deformed bar. Each steel mill which rolls deformed bars may have a different pattern of deformation on the bar, but all are rolled to conform to ASTM specifications. Some of the types of deformation patterns are shown in Figure 29-3-1.

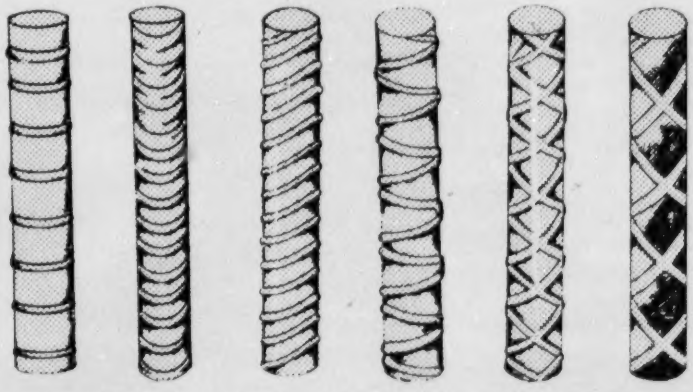


Figure 29-3-1. Types of Deformed Bars

Plain bars are smooth, round bars without deformations on them. Plain bars are not generally used for reinforcing, but for special purposes such as sliding dowels at expansion joints.

Reinforcing bars are manufactured in several grades which are described in ASTM standard specifications, marked and color coded before shipping. The "grade" designations of the bars refer to the minimum yield strength (nominal rating) of the steel. The most commonly used materials are as follows:

(1) ASTM A615 Billet Steel Bars for Concrete Reinforcement

Grade 40 (40,000 psi min. yield strength)

Grade 60 (60,000 psi min. yield strength)

Grade 75 (75,000 psi min. yield strength)

(2) ASTM A616 Rail Steel Bars for Concrete Reinforcement

Grade 50

Grade 60

(3) ASTM A617 Axle Steel Bars for Concrete Reinforcement

Grade 40

Grade 60

Deformed bars are available in eleven standard sizes, designated by numbers. The number denotes approximately the diameter of the bar in eighths of inches. For example, a #4 bar has an approximate diameter of 4/8 or 1/2 inch. The standard bars, which are defined by size and weight in the applicable ASTM specifications, are listed in Table 29-3-2.

Table 29-3-2

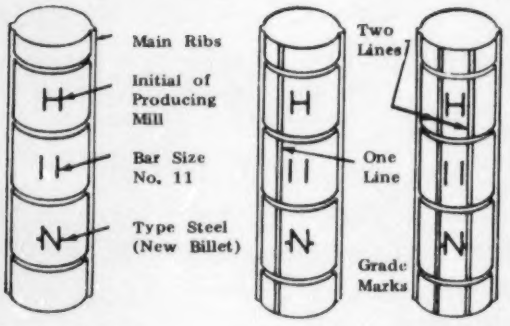
ASTM STANDARD REINFORCING BARS				
BAR SIZE DESIGNATION	WEIGHT POUNDS PER FOOT	NOMINAL DIMENSIONS—ROUND SECTIONS		
		DIAMETER INCHES	CROSS SECTIONAL AREA SQ. INCHES	PERIMETER INCHES
#3	.376	.375	.11	1.178
#4	.668	.500	.20	1.571
#5	1.043	.625	.31	1.963
#6	1.502	.750	.44	2.356
#7	2.044	.875	.60	2.749
#8	2.670	1.000	.79	3.142
#9	3.400	1.128	1.00	3.544
#10	4.303	1.270	1.27	3.990
#11	5.313	1.410	1.56	4.430
#14	7.65	1.693	2.25	5.32
#18	13.60	2.257	4.00	7.09

Different sizes and grades of bars are frequently used on the same construction site, and a means of identification is therefore important. ASTM specifications require that each bar producer roll the following identification marking on each bar.

(1) mill symbol or letter
(2) number corresponding to bar size
(3) type of steel
(4) grade designation

Two bar marking systems which are used by producers are illustrated in Figure 2.

Welded wire fabric reinforcing consists of cold-drawn logitudinal or carrying wires, and usually smaller transverse wires or ties. The two sets of wires are connected at the intersections by welds. Various combinations of wire sizes and spacings are available with longitudinal spacing from 2 in. to 6 in., and transverse spacing from 8 in. to 16 in.

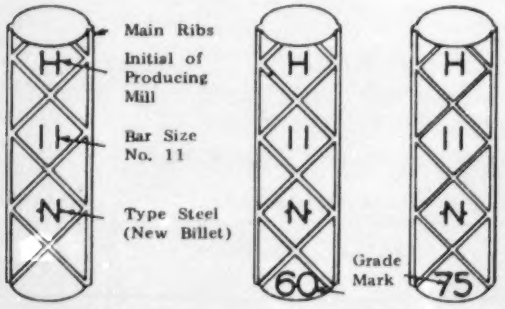


GRADE 40
GRADE 50

GRADE 60

GRADE 75
No. 11, No. 14 & No. 18 Only

Continuous longitudinal smaller lines between the main longitudinal ribs. One small line identifies Grade 60, two such lines, Grade 75.



GRADE 40
GRADE 50

GRADE 60

GRADE 75
No. 11, No. 14 & No. 18 Only

Rolled-on numbers follow the symbols and number that indicate bar size. The number "60" identifies Grade 60; the number "75", Grade 75.

Figure 29-3-2. Deformed Bar Marking Systems

MATERIALS HANDLING AND STORAGE

The consistent production of uniform, quality concrete requires proper handling and storage of the component materials. The following describes the practices generally employed in the construction industry related to these materials.

Cements

Cements may be purchased in loose, bulk quantities, or individual sacks. Regardless of the quantity, all cement should be stored in weathertight, properly ventilated structures to prevent the absorption of moisture.

Bulk cement is transported in truck tankers or railroad tank cars to the storage facilities at the concrete batch plant or the construction site where the material is usually unloaded with air pressure. The storage vessels, called cement silos, are covered cylindrical tanks with sloped bottoms usually equipped with air diffuser flow pads through which small quantities of low pressure air may be introduced intermittently to loosen settled cement. The silos may be divided into two or more compartments to provide segregated storage for different types of cement. Each compartment from which cement is batched normally includes a separate gate and a conveyance such as a screw conveyor, air slide, or rotary feeder to provide constant flow and precise cut-off characteristics for accurate batching and weighing.

Sacked cement may be transported by truck or rail, and should be stored in a sheltered area on pallets or platforms to permit circulation of air and avoid contact with ground or floor dampness.

Aggregates

Fine and coarse aggregates delivered to the concrete batcher must be of good quality and uniform in grading and moisture content.

Coarse aggregates are usually separated into several size fractions and batched separately to minimize segregation. Segregation is the separation of different sizes of materials within a mixture (e.g., the settling out of fines in a stock pile of coarse aggregate material).

Fine aggregates (sand) should be controlled to minimize variations in grading and to keep finer fractions uniform.

Improper handling and stockpiling methods cause segregation, breakage and contamination. The following suggested practices should be followed to minimize these effects:

(1) Stockpiling should be done on a hard base with with adequate drainage, preferably concrete, to prevent contamination from underlying material.

(2) Aggregates should not be dumped onto a sloped surface and allowed to run down and segregate.

(3) Trucks, bulldozers or other vehicular or track equipment should not be operated on the stockpiles because they may (a) break or crush the aggregate or (b) track dirt or other contaminants onto the piles.

(4) Stockpiles should not be contaminated by swinging aggregate filled buckets or clams over various stockpiled aggregate sizes.

(5) Intermixing of stockpiled materials should be prevented by the use of walls or ample spacing between piles.

Admixtures

Chemical admixtures in liquid form should be stored in watertight drums or tanks and protected from freezing. Chemical admixtures supplied in solid form are usually converted to liquid for dispensing into the concrete batcher.

These should then be stored in similar closed vessels which are equipped with agitation or mixing equipment to keep the solids in suspension and also protected from freezing.

Pozzolans and other dry additives should be handled and stored in the same manner as cement. Proper storage is particularly important to provide protection from dampness and contamination and to minimize lumping and warehouse set. Since the appearance of finely divided mineral admixtures is quite often similar to that of portland cement, storage and handling equipment should be clearly identified and marked and precautions taken to assure that leakage between storage compartments or carry-over contamination does not occur.

Reinforcing Steel

Reinforcing steel materials are generally delivered to the construction site on flatbed trucks or rail cars. Bundles of bars may be hoisted or skidded to the ground onto wood timbers to keep them free from mud and to provide for easy rehandling.

Straight bars are usually grouped by sizes and by lengths within a size so that easy identification is possible. Bent bars are similarly stockpiled and the tags of both straight and bent bars are kept at the same end for easy identification. When a bundle is opened and some of the bars are removed, the bar with the tag should remain with the bundle. (Normally only one bar in each bundle is tagged.) Hoists such as truck cranes, tower cranes and stiff-leg derricks are used to bundle reinforcing steel. When hoisting bundles of bars thirty feet or longer, it is necessary to use a spreader bar as illustrated in Figure 29-3-3 so that the bars will not bend excessively.

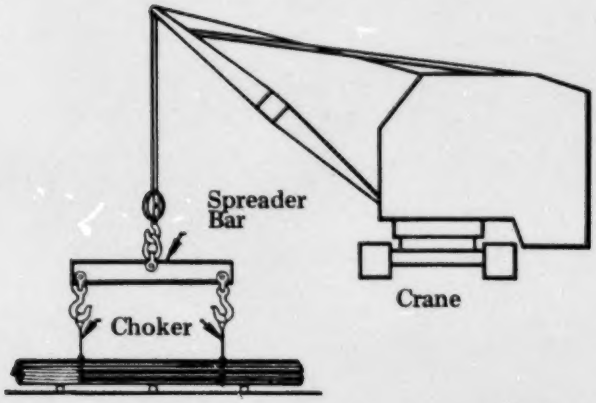


Figure 29-3-3. Use of Spreader Bar

The spreader bar should be at least one-half the length of the bars in the bundle and may be fabricated from a piece of heavy pipe or an I-beam.

For bundles of bars under thirty feet in length, a bridle/choker rig, as illustrated in Figure 29-3-4 is most commonly used.

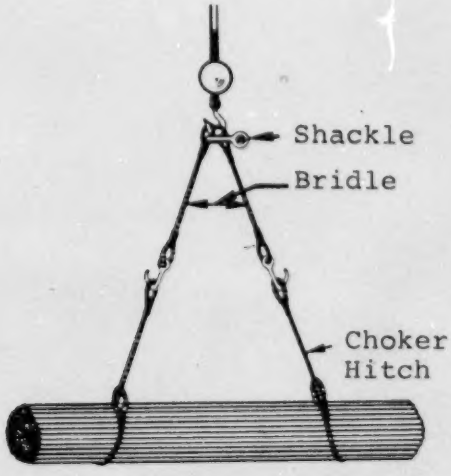


Figure 29-3-4. Use of Bridle/Choker Rig

CONCRETE MATERIALS SELECTION

For any particular job, the concrete to be used must be "designed" to produce certain characteristics. The component materials and their proportions are selected to produce these desired characteristics which include strength, durability, workability, and optimum cost. It should be noted that these criteria conflict with each other: a concrete mix of maximum strength is not necessarily the most durable or workable and certainly not the least expensive. Acceptable levels, then, for each criterion must be established, and the "design mix" established accordingly.

Cement manufacturers or suppliers in any particular area will usually recommend design mixes to fit the users' requirements and the aggregate materials available. If it is to be used for a large construction project, the user generally has concrete samples of the mix made and physically tested to verify the acceptability of the design mix. If the test results indicate that the design mix is acceptable and as economical as possible, it will be used for production. If the samples fail to meet any of the requirements, adjustments will be made in the design mix and new samples made and tested.

MATERIALS UNIFORMITY

Experience and analysis of concrete component materials are used to develop design mixes and to predict strength, durability, workability and cost. Any variability or lack of uniformity of the component materials, however, will be reflected and first detected in the strength of the concrete.

On large construction projects, such as nuclear power plants, during concreting operations, mixed concrete is sampled, formed into test cylinders, and destructively tested to measure strength characteristics. Test results are recorded and plotted and any degradation in quality is easily recognized.

Concrete derives its strength from the hardness and compressive strength of the aggregate particles and the strength of the hardened cement paste binder. The strength of the cement binder is dependent on the amount of water and admixtures which have been used. The remainder of this section describes the effects on concrete strength of variations in cement, water, aggregates and admixtures.

Cement

Cement reacts with water and hardens. The amount of water that is used in any concrete mixture is known as the water-cement ratio, and is expressed as a "weight ratio" or as "gallons of water per sack of cement" (cement content is expressed as sacks of cement per cubic yard of concrete). To obtain plastic mixtures which will coat all of the particles and pieces of aggregate, more water must be used than can be combined chemically with the cement. The excess water will eventually evaporate from the hardened mass and leave voids which tend to reduce watertightness and strength of the concrete. No more water should be used than is necessary for the required chemical action and plasticity.

Any variations in the physical or chemical properties of the cement used will produce variations in the strength, durability and set-time of the concrete produced. Most cement used on construction projects is manufactured to standard specification, such as ASTM C150 for portland cement. When requested in the purchase order, the cement

manufacturer will certify to the purchaser that the material supplied meets the requirements of the specification invoked. The user may accept the manufacturer's certification or take samples of the cement and have tests performed to verify the acceptability of the material. Different cements of the same type meeting the specification requirements usually produce uniform concrete mixtures which have similar qualities with only minor (acceptable) variations.

Aggregates

Mineral aggregates constitute about 70 to 80 percent of the typical concrete mixture and, consequently, their uniformity and quality characteristics are reflected directly in the concrete in which they are used. Aggregates may be purchased in accordance with a standard specification, such as ASTM C33. This specification defines the requirements for both fine and coarse aggregates, and provides limits for size grading, deleterious substances, soundness and physical properties. Variations in any of these categories will alter the water requirements of the concrete mixture which will change the water-cement ratio and alter the concrete durability and strength.

Aggregates may be encountered at times with different chemical compositions which are susceptible to harmful chemical reactions. Such reactions may result in abnormal expansion, cracking or loss of strength of the concrete. The three most common types of reactions are the (1) alkali-aggregate reaction, (2) the cement-aggregate reaction, and (3) the carbonate aggregate reaction.

The alkali-aggregate reaction occurs when alkalies (Na_2O and K_2O) from the cement react with siliceous constituents which are sometimes present in the aggregates. Aggregates with these properties have generally been found in the western half of the United States.

The cement-aggregate reaction is a chemical phenomenon occurring with certain sand-gravel aggregates found in Kansas, Nebraska and Wyoming, but the reaction is not caused by the alkali content of the cement. The phenomenon can be identified, but the mechanism involved in the concrete deterioration has not been specifically determined.

Aggregates in some areas of Canada, Iowa and Indiana which contain approximately equal amounts of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) have exhibited reactivity with cement alkalies, which is known as the carbonate aggregate reaction. This reaction has also produced aggregate expansion and consequent cracking of the concrete.

For large projects, it is advisable to sample all aggregate materials in advance and to perform laboratory tests for potential chemical reactivity, to preclude possible concrete deterioration from these causes. There are no known methods of adequately preserving existing concrete which contains the elements that contribute to the previously described chemical reactions.

Many other properties of concrete are also influenced by aggregate properties. Table 29-3-3 summarizes many specific concrete properties and the relevant, or influencing, aggregate characteristics.

Table 29-3-3. Properties of Concrete Influenced by Aggregate Properties

Concrete Property	Relevant Aggregate Property
Durability:	
Resistance to freezing and thawing	Soundness Porosity Pore structure Permeability Degree of saturation Tensile strength Texture and structure Presence of clay
Resistance to wetting and drying	Pore structure Modulus of elesticity
Resistance to heating and cooling	Coefficient of thermal expansion
Abrasion Resistance	Hardness
Alkali-aggregate reaction	Presence of particular siliceous constituents
Strength	Strength Surface texture Cleanness Particle shape Maximum size
Shrinkage	Modulus of elasticity Particle shape Grading Cleanness Maximum size Presence of clay
Coefficient of thermal expansion	Coefficient of thermal expansion Modulus of elasticity
Thermal conductivity	Thermal conductivity
Specific heat	Specific heat
Unit weight	Specific gravity Particle shape Grading Maximum size

Table 29-3-3 (cont'd). Properties of Concrete Influenced by Aggregate Properties

Concrete Property	Relevant Aggregate Property
Modulus of elasticity	Modulus of elasticity Poisson's ratio
Slipperiness	Tendency to polish
Economy	Particle shape Grading Maximum size Amount of processing required Availability

Admixtures

Admixtures are used to modify or improve certain properties of concrete. Typically, relatively small quantities of admixture materials are used in the concrete batch (only a small amount is required to produce the desired effect). Variations, then, in either the admixture material or the quantity used may produce a significant variation in the resulting concrete. Every precaution must be taken to assure uniformity of the materials and extreme accuracy in their measurement.

Water

The water content, or water-cement ratio, of the concrete mixture is the most important factor to concrete strength and durability. In general, potable water, or water suitable for drinking, is suitable for concrete mixing. Precise control of the water content must be maintained during concrete batching, including precise compensation for the moisture contained in the aggregate materials.

Figure 29-3-5 illustrates the effect of the water-cement ratio on 2 typical samples of concrete (air-entrained and non-air-entrained). As the water-cement ratio in the

air-entrained concrete specimen increases from 0.40 to 0.60, the compressive strength at 28 days decreases from 4800 psi to 2700 psi, or a 44% loss in strength. As the water-cement ratio in the non-air-entrained specimen increases from 0.40 to 0.60, the compressive strength at 28 days decreases from 5800 psi to 3700 psi, or a 36% loss in strength. This illustrates how over-utilization of water to make the concrete mixture more fluid for convenience in the field can drastically lower its ultimate strength.

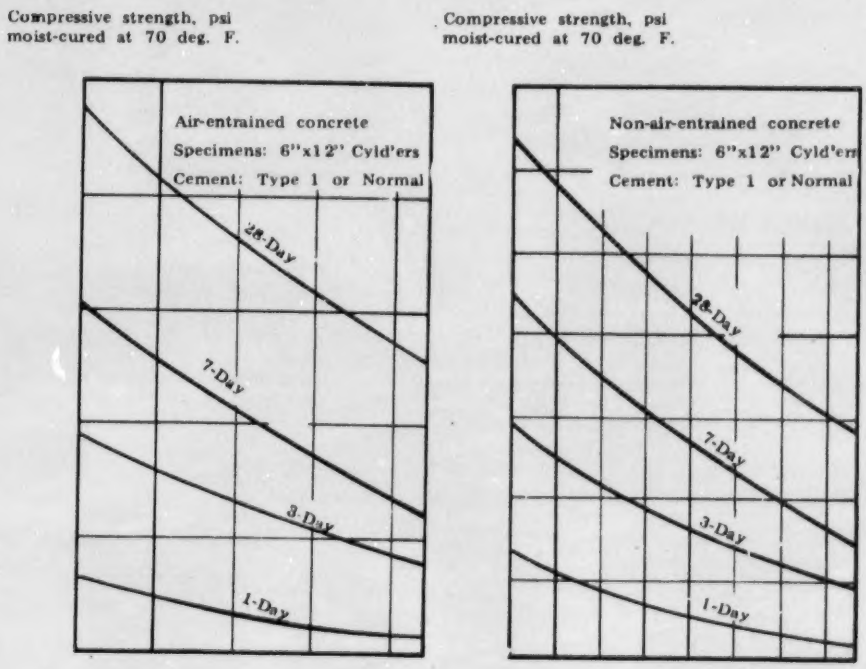


Figure 29-3-5. Effect of Water-Cement Ratio Variations Concrete Strength

MATERIALS ACCEPTANCE

The quality and uniformity of concrete can only be controlled when consistently uniform, acceptable component materials are used. It is important that specifications be established for all component materials, and that the materials supplied be monitored and periodically tested to verify conformance to the specification requirements.

The standard specifications generally accepted and used by the construction industry are those developed and published by the ASTM.

Typical Material Standards

Portland Cement

Portland cements are manufactured in accordance with ASTM standard C150. When purchasing portland cements, it is recommended that this specification and the cement type (I, II, III, etc.) be included in the purchase specification. The purchaser may also request a manufacturer's certification that the material was tested in accordance with the C150 specification, together with a report of the actual test results.

The standard chemical and physical requirements as specified in ASTM C150 are listed in Tables 29-3-4 and 29-3-5.

Table 29-3-4. ASTM C150 Standard Chemical Requirements for Portland Cement

Cement Type	I and IA	II and IIIA	III and IIIA	IV	V
Silicon dioxide (SiO_2), min, percent	----	21.0	----	----	----
Aluminum oxide (Al_2O_3), max, percent	----	6.0	----	----	----
Ferric oxide (Fe_2O_3), max, percent	----	6.0	----	6.5	----
Magnesium oxide (MgO), max, percent	5.0	5.0	5.0	5.0	5.0
Sulfur trioxide (SO_3), max, percent					
When (3 CaO · Al_2O_3)[a] is 8 percent or less	3.0	3.0	3.5	2.3	2.3
When (3 CaO · Al_2O_3)[a] is more than 8 percent	3.5	b	4.5	b	b
Loss on ignition, max, percent	3.0	3.0	3.0	2.5	3.0
Insoluble residue, max, percent	0.75	0.75	0.75	0.75	0.75
Tricalcium silicate (3 CaO · SiO_2)[a] max, percent	----	----	----	35	----
Dicalcium silicate (2 CaO · SiO_2)[a] min, percent	----	----	----	40	----
Tricalcium aluminate (3 CaO · Al_2O_3)[a] max, percent	----	8	15	7	5
Tetracalcium aluminoferrite plus twice the tricalcium aluminate[a] (4 CaO · Al_2O_3 · Fe_2O_3 + 2(3 CaO · Al_2O_3)), or solid solution (4 CaO · Al_2O_3 · Fe_2O_3 + 2 CaO · Fe_2O_3), as applicable, max, percent	----	----	----	----	20.0

[a] The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds.

When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

Tricalcium silicate = (4.071 x percent CaO) - (7.600 x percent SiO_2) - (6.718 x percent Al_2O_3) - 1.430 x percent Fe_2O_3) - (2.852 x percent SO_3

Dicalcium silicate = (2.867 x percent SiO_2) - (9.7544 x percent C_3S)

Tricalcium aluminate = (2.650 x percent Al_2O_3) - (1.692 x percent Fe_2O_3)

Tetracalcium aluminoferrite = 3.043 x percent Fe_2O_3

When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution (expressed as ss ($C_4AlFe + C_3Al$)) is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

ss ($C_4AlFe + C_3Al$) = (2.100 x percent Al_2O_3) + (1.702 x percent Fe_2O_3)

Tricalcium silicate = (4.071 percent CaO) - (7.600 x percent SiO_2) - (4.479 x percent Al_2O_3) - (2.859 x percent Fe_2O_3) - (2.852 x percent SO_3)

No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as previously shown.

Table 29-3-4 (cont'd). ASTM C150 Standard Chemical Requirements for Portland Cement

In the calculation of C_3A, the values of Al_2O_3 determined to nearest 0.01 percent shall be used. In the calculation of other compounds the oxides determined to the nearest 0.1 percent shall be used.

Values for C_3A and for the sum of $C_4AlFe + C_3A$ shall be reported to the nearest 0.1 percent. for other compounds shall be reported to the nearest 1 percent.

[b] Not applicable.

Table 29-3-5. ASTM C150 Standard Physical Requirements for Portland Cement

Cement Type	I	IA	II	IIA	III	IIIA	IV	V
Air content of mortar,[a] volume percent:								
max	12	22	12	22	12	22	12	12
min		16		16		16		
Fineness, specific surface, cm^2/g (alternative methods):[b]								
Turbidimeter test, min	1600	1600	1600	1600			1600	1600
Air permeability test, min	2800	2800	2800	2800			2800	2800
Soundness								
Autoclave expansion, max, percent	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Strength, not less than the values shown for the ages indicated below:[c]								
Compressive strength, psi (MPa)								
1 day					1800 (12.4)	1450 (10.0)		
3 days	1800 (12.4)	1450 (10.0)	1500 (10.3)	1200 (8.3)	3500 (24.1)	2800 (19.3)		
			1000[e] (6.9)[e]	800[e] (5.5)[e]				
7 days	2800 (19.3)	2250 (15.5)	2500 (17.2)	2000 (13.8)			1000 (6.9)	2200 (15.2)
			1700[e] (11.7)[e]	1350[e] (9.4)[e]				
28 days							2500 (15.5)	3000 (20.7)
Time of setting (alternative methods):[d]								
Gillmore test:								
Initial set, min, not less than	60		60	60	60	60	60	60
Final set, h, not more than	10		10	10	10	10	10	10
Vicat test:								
Initial set, min, not less than	45		45	45	45	45	45	45
Final set, h, not more than	8		8	8	8	8	8	8

Table 29-3-5 (cont'd). ASTM C150 Standard Physical Requirements for Portland Cement

[a] Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.

[b] Either of the two alternative fineness methods may be used at the option of the testing laboratory. However, in case of dispute, or when the sample fails to meet the requirements of the air-permeability test, the turbidimeter test shall be used, and the requirements in this table for the turbidimetric method shall govern.

[c] The strength at any age shall be higher than the strength at any preceding age.

[d] The purchaser should specify the type of setting-time test required. In case he does not so specify, or in case of dispute, the requirements of the Vicat test only shall govern.

[e] When the optional heat of hydration or the chemical limit on the sum of the ricalcium silicate and tricalcium aluminate is specified.

Cement users usually do not perform chemical or physical tests on material received. Normally, for large projects, the manufacturer tests and certifies each batch of cement that is shipped. Occasionally, samples may be taken for verification by an independent laboratory, but the manufacturer's reports are usually used as a basis for accepting the material.

Aggregates

Specifications based on tests and past service records may be developed and used for specific aggregate materials available in local areas, or standard specifications such as those published by the ASTM may be used when the specification is appropriate for the material available.

ASTM C33, Standard Specifications for Concrete Aggregates is a typical standard used in the construction industry and provides standards for Fine Aggregate and for Coarse Aggregate. Some of the requirements listed in ASTM C33 are as follows:

Fine Aggregate

Fine aggregate shall be graded in accordance with the sieve analysis limits listed in the specification and shall have a fineness modulus of not less than 2.3 or more than 3.1.

Deleterious substances shall not exceed the limits prescribed in Table 29-3-6.

Table 29-3-6. Limits for Deleterious Substances in Fine Aggregate for Concrete

Item	Weight Percent of Total Sample, max
Clay lumps and friable particles	3.0
Material finer than 75-μm (No. 200) sieve:	
Concrete subject to abrasion	3.0[a]
All other concrete	5.0[a]
Coal and lignite:	
Where surface appearance of concrete is of importance	0.5
All other concrete	1.0

[a]In the case of manufactured sand, if the material finer than the 75-μm (No. 200) sieve consists of the dust of fracture, essentially free from clay or shale, these limits may be increased to 5 and 7%, respectively.

Other requirements for fine aggregate covered in the specification include: variation in fineness modulus, organiz impurities and soundness.

Coarse Aggregate

Coarse aggregates shall be graded between the limits specified and shall conform to the requirements prescribed in Table 29-3-7.

The specification (C33) defines "weathering regions" in the U.S.A. and designates classes of concrete construction as a basis for coarse aggregate requirements. The weathering regions are illustrated on the map in Figure 29-3-6. The class designation, 1 through 5 are listed in Table 29-3-8 along with limits for deleterious substances and physical properties.

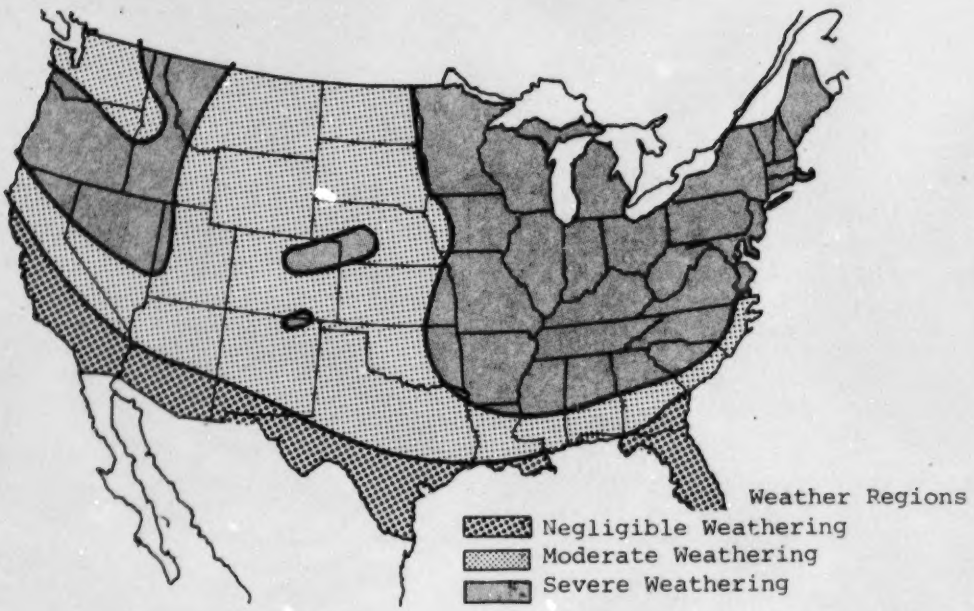


Figure 29-3-6
Concrete Weathering Regions in the USA

Table 29-3-7. Grading Requirements for for Coarse Aggregates

Size Number	Nominal Size (Sieves with Square Openings)	Amounts Finer than Each Laboratory Sieve (Square Openings), Weight Percent												
		100 mm (4 in.)	90 mm (3½ in.)	75 mm (3 in.)	63 mm (2½ in.)	50 mm (2 in.)	37.5 mm (1½ in.)	25.0 mm (1 in.)	19.0 mm (¾ in.)	12.5 mm (½ in.)	9.5 mm (⅜ in.)	4.75-mm (No. 4)	2.36-mm (No. 8)	1.18-mm (No. 16)
1	90 to 38.1 mm (3½ to 1½ in.)	100	90 to 100		25 to 60		0 to 15		0 to 5					
2	63 to 38.1 mm (2½ to 1½ in.)			100	90 to 100	35 to 70	0 to 15		0 to 5					
357	50 to 4.75 mm (2 in. to No. 4)				100	95 to 100		35 to 70		10 to 30		0 to 5		
467	38.1 to 4.75 mm (1½ in. to No. 4)					100	95 to 100		35 to 70		10 to 30	0 to 5		
57	25.0 to 4.75 mm (1 in. to No. 4)						100	95 to 100		25 to 60		0 to 10	0 to 5	
67	19.0 to 4.75 mm (¾ in. to No. 4)							100	90 to 100		20 to 55	0 to 10	0 to 5	
7	12.5 to 4.75 mm (½ in. to No. 4)								100	90 to 100	40 to 70	0 to 15	0 to 5	
8	9.5 to 2.36 mm (⅜ in. to No. 8)									100	85 to 100	10 to 30	0 to 10	0 to 5
3	50 to 25.0 mm (2 to 1 in.)				100	90 to 100	35 to 70	0 to 15		0 to 5				
4	38.1 to 19.0 mm (1½ to ¾ in.)					100	90 to 100	20 to 55	0 to 15		0 to 5			

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Table 29-3-8. Class Designations, Limits for Deleterious Substances, and Physical Property Requirements of Coarse Aggregate for Concrete

Class Designation*	Type or Location of Concrete Construction	Maximum Allowable, %						
		Clay Lumps and Friable Particles	Chert (Less Than 2.40 sp gr SSD)[c]	Sum of Clay Lumps, Friable Particles and Chert (Less Than 2.40 sp gr SSD)[c]	Material Finer Than 75-μm (No. 200) Sieve	Coal and Lignite	Abrasion[a]	Magnesium Sulfate Soundness (5-cycles)[b]
		Severe Weathering Regions						
1S	Footings, foundations, columns and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	---	----	1.0[d]	1.0	50	--
2S	Interior floors without coverings	5.0	---	----	1.0[d]	0.5	50	--
3S	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather	5.0	5.0	5.0	1.0[d]	0.5	50	18
4S	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures, subject to frequent wetting	3.0	5.0	5.0	1.0[d]	0.5	50	18
5S	Exposed architectural concrete	2.0	3.0	3.0	1.0[d]	0.5	50	18
		Moderate Weathering Regions						
1M	Footings, foundations, columns and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	---	----	1.0[d]	1.0	50	--

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Table 29-3-34 (cont'd). Class Designations, Limits for Deleterious Substances, and Physical Property Requirements of Coarse Aggregate for Concrete

Class Designation*	Type or location of Concrete Construction	Clay Lumps and Friable Particles	Chert (Less Than 2.40 sp gr SSD)[c]	Sum of Clay Lumps, Friable Particles and Chert (Less Than 2.40 sp gr SSD)[c]	Material Finer Than 75-μm (No. 200) Sieve	Coal and Lignite	Abrasion[a]	Magnesium Sulfate Soundness (5-cycles)[b]
3M	Interior floors without coverings	5.0	---	----	1.0[d]	0.5	50	--
5M	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather[e]	5.0	8.0	10.0	1.0[d]	0.5	50	18
4M	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures[e] subject to frequent wetting	5.0	5.0	7.0	1.0[d]	0.5	50	18
6M	Exposed architectural concrete[e]	3.0	3.0	5.0	1.0[d]	0.5	50	18
	Negligible Weathering Regions							
1N	Slabs subject to traffic abrasion, bridge decks, floors, sidewalks, pavements[e]	5.0	---	----	1.0[d]	0.5	50	--
2N	All other classes of concrete[e]	10.0	000	----	1.0[d]	1.0	50	--

[a] Crushed air-cooled blast-furnace slag is excluded from the abrasion requirements. The compact unit weight of crushed air-cooled blast furnace slag shall be not less than 70 lb/ft^3 (1120 kg/m^3). The grading of slag used in the unit weight test shall conform to the grading to be used in the concrete. Abrasion loss of gravel, crushed gravel, or crushed stone shall be determined on the test size or sizes most nearly corresponding to the grading or gradings to be used in the concrete. When more than one grading is to be used the limit on abrasion loss shall apply to each.

Table 29-3-8 (cont'd). Class Designations, Limits for Deleterious Substances, and Physical Property Requirements of Coarse Aggregate for Concrete

[b] The allowable limits for soundness shall be 12% if sodium sulfate is used.

[c] These limitations apply only to aggregates in which chert appears as an impurity. They are not applicable to gravels that are predominantly chert. Limitations on soundness of such aggregates must be based on service records in the environment in which they are used.

[d] In the case of crushed aggregates, if the material finer than the 75-μm (No. 200) sieve consists of the dust of fracture, essentially free of clay or shale, this percentage may be increased to 1.5. A greater amount of dust of fracture passing the 75-μm sieve may be permitted provided the amount passing the 75-μm sieve in the fine aggregate is less than the specified maximu. In such case, the sum of the amounts finer than the 75-μm sieve from the separate fine and coarse aggregates shall not exceed the sum of the weighted maximum amounts permitted for the coarse plus fine aggregate.

[e] For construction at altitudes exceeding 5000 ft. above sea level, the requirements of the "Severe Weathering Region" shall apply.

* Suffix letters indicate weathering condition; S - Severe, M - Moderate, and N - Negligible.

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Aggregate users usually either perform tests on the purchased materials, or have tests performed by a testing laboratory to verify the suitability and acceptability of materials received. Some of the tests frequently performed are as follows:

Particle size distribution (grading, gradation, sieve analysis)

Reference specification: ASTM C136

Particle size distribution has an effect on all the properties of concrete related to water requirement. The sieve analysis is probably the most frequently made of all aggregate tests. The particle size distribution is determined directly by passing samples of the aggregate through a nest of sieves of successively smaller openings and weighing the material retained on each sieve.

Specific gravity

Reference specifications: Coarse aggregate, ASTM C127; Fine aggregate, ASTM C128

An accurate knowledge of the specific gravity of both fine and coarse aggregate is required to calculate the batch weights of materials to be used.

Unit weight

Reference specification: ASTM C29

The dry, rodded unit weight, together with the specific gravity, provides a means for computing the voids in a unit volume of aggregate. In mixture proportioning, it provides a basis for estimating the amount of cement required for a given coarse aggregate.

Absorption

Reference specification: ASTM C127, C128

Aggregate absorption is determined directly from the weights of a sample in the saturated surface-dry and over-dry conditions, and is required for determining surface moisture on samples of the same material by the oven drying method.

Surface moisture

Reference specification: ASTM C127, C128

A knowledge of surface moisture is essential for proportioning and controlling mixing water. Water carried into the concrete mixer on the aggregate must be subtracted from the weight of water added while the quantity of aggregate must be increased by an equal amount. Surface moisture is commonly determined by oven drying a sample and subtracting from the total water content the amount of absorbed water.

Admixtures

The specifications which are most widely used and cover those types or classes that make up the bulk of current production admixtures are listed in Table 29-3-9.

Table 29-3-9. Specifications for Concrete Admixtures

ASTM D 98	Calcium Chloride
ASTM C 260	Air-Entraining Admixtures
AASHO M 154	Air-Entraining Admixtures
CRD-C 13	Air-Entraining Admixtures
ASTM C 618	Fly Ash and Raw or Calcined Natural Pozzolans
Federal Specification SS-P-570b	Pozzolans
CRD-C 262	Pozzolan
ASTM C 494	Chemical Admixtures
CRD-C 87	Chemical Admixtures
USBR	Water-Reducing Set-Controlling Admixtures

A typical specification for air entraining admixtures is ASTM C260. This specification includes the following performance requirements:

(1) The bleeding of concrete made with the test admixture shall not exceed that of concrete made with a reference admixture by more than 2 percent.

(2) Both the initial and final times of setting of concrete containing the test admixture shall not deviate from that of the concrete made with a reference admixture by more than $\pm$ 1 hour and 15 minutes.

(3) The compressive strength at any test age of concrete containing the admixture under test shall be not less than 90 percent of that of similar concrete containing the reference admixture at the same test age.

Standard test methods are available to evaluate admixtures from the user's viewpoint. Some of these tests are listed in Table 29-3-10. Although such tests are valuable for selecting and accepting admixture products, any substantial use of continuously produced concrete should be preceded by testing that allows observation and measurement of the performance of the product under concrete plant operating conditions in combination with the concrete component materials then in use.

Admixtures are usually tested for acceptance for one or more of four reasons: (1) to determine compliance with the purchase specification, (2) to evaluate the effect of the admixture on the properties of the concrete to be made under the anticipated conditions, (3) to determine within lot uniformity, and (4) to provide data showing that any lot is the same as those previously supplied.

The specifications listed in Table 29-3-10 are typical of those in current use for testing various concrete admixtures.

Table 29-3-10. Admixture Testing Specifications

ASTM C233	Testing Air-Entraining Admixtures for Concrete
ASTM C441	Test for Effectiveness of Mineral Admixtures in Preventing Excessive Expansion of Concrete due to the Alkali-Aggregate Reaction
ASTM C311	Sampling and Testing Fly Ash for Use as an Admixture in Portland Cement Concrete
ASTM C494	Chemical Admixtures for Concrete

Reinforcing Steel Bars

Deformed concrete reinforcing bars rolled from billet steel are produced to the requirements of ASTM A615 or A706. ASTM A615 is specified for most applications, and A706 for special applications requiring a combination of higher strength, weldability, ductility and improved bending properties.

Bars are available in two grades under ASTM A615 and one grade under ASTM A706. The required mechanical properties are listed in Table 29-3-11.

Table 29-3-11. Mechanical Properties of Hot Rolled Deformed Concrete Reinforcing Bars

	Tensile Strength, Min. PSI	Yield, Min. PSI
ASTM A615, Gr. 40	70,000*	40,000
ASTM A615, Gr. 60	90,000*	60,000
ASTM A706 (one grade)	80,000*	60,000

*Tensile strength shall not be less than 1.25 times the actual yield strength.

A bend test is required by ASTM A615 for bar sizes 3 to 11. ASTM A706 requires a bend test on all bar sizes. The pin diameters and degree of bend vary with the grade and bar size as designated in the two ASTM standards.

The chemical composition of the steel affects the mechanical properties. The extent to which certain elements are present is at the option of the reinforcing bar producer when producing for conformance to ASTM A615. The maximum cast or heat analysis for phosphorous in ASTM A615 is 0.05 percent. The composition limits of ASTM A706 are listed in Table 29-3-12 and the maximum carbon content must not exceed a specified value given in ASTM A706.

Table 29-3-12. Chemical Composition Limits for ASTM A706 Steel Bars

Element	Max. Percent
Carbon	0.03
Manganese	1.50
Phosphorous	0.035
Sulfur	0.045
Silicon	0.50

EXERCISES

1. Portland Cement

Samples of three shipments of Portland Cement are received for acceptance evaluation. Test report data for each sample is shown below. In accordance with the requirements shown in Tables 29-3-4 and 29-3-5 determine the disposition of each sample, and list the reasons for the accept/reject decisions:

Cement Sample: / Type Cement:	A I	B II	C IV
SiO_2, %	not reported	23.7	not reported
Al_2O_3, %	not reported	4.81	not reported
Fe_2O_3, %	not reported	3.65	not reported
MgO, %	4.31	2.98	6.9
Loss on Ignition, %	1.75	2.15	3.1
Insoluble Residue, %	0.69	0.48	0.89
Air Content of Mortar, Vol. %	9.35	13.15	11.30
Compressive Strength			
1 day, psi	not reported	not reported	not reported
3 days, psi	1875	1360	not reported
7 days, psi	2980	2310	1050
28 days	not reported	not reported	2580
Time of Setting Vicat Test: Initial Set, Min.	43	53	58
Final Set, Hr.	4.9	9.1	9.8

2. Fine Aggregates

The test data from test reports of representative samples of three fine aggregate shipments are shown below. Using the information provided in this text, determine the disposition of each sample, and list the reasons for the accept/reject decisions: (Note: the material will be used for back filled foundation concrete).

Aggregate Sample	A	B	C
Fineness Modulus	2.8	2.6	3.0
Clay lumps and friable particles, et. %	2.3	2.7	3.4
Material finer than 75-μm (No. 200) sieve, wt. %	3.4	4.5	4.1
Coal and Lignite, wt. %	0.7	0.6	1.7

3. Coarse Aggregates

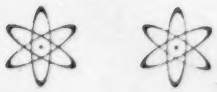
The test data from test reports of representative samples of three coarse aggregate shipments are shown below. Using the information provided in this text, determine the disposition of each sample, and list the reasons for the accept/reject decisions: (Note: the material will be used for exposed floors and porches under moderate weathering conditions).

Aggregate Sample	A	B	C
Clay lumps and friable particles, %	3.7	4.2	5.9
Chert (less than 2.40 sp. gr.), %	2.1	2.4	6.8
Coal and lignite, %	1.3	0.2	0.6
Abrasion, %	21	37	39
$HgSO_4$ soundness ($NaSO_4$ used)	13.9	10.7	17.5

4. Reinforcing Steel Bars

The test data from test reports of representative samples of four lots of deformed bars are shown below. Using the information provided in this text determine the disposition of each lot, and list the reasons for the accept/reject decisions.

Sample	A	B	C	D
Type (ASTM)	A615	A615	A706	A615
Grade	60	40	--	60
Yield, psi	74,800	43,800	65,500	63,400
Tensile, psi	92,700	74,900	83,800	87,200



MATERIALS

The following materials are used to support this module:

1. Samples of various sizes and grades of rebar.
2. Samples of various aggregates and admixtures.

PROCEDURES

1. Visually inspect rebar for compliance with marking requirements.
2. Visually examine sample aggregates. Discuss importance of shape, range of sizes, and fines.
3. Tour a concrete supplier's facilities. Note practices in the following areas and discuss notes in class:
   a. storage of cements
   b. storage of aggregates
   c. water supply and quality
   d. batch definition
   e. batch weighing and mixing
   f. testing

DATA TABLE

None

REFERENCE MATERIALS

ACI Manual of Concrete Practice, American Concrete Institute, Detroit, Michigan

Materials, Design and Control of Quality Concrete, Protex Industries, Inc., Denver, Colorado

Control of Quality of Ready-Mixed Concrete, National Ready Mixed Concrete Association, Silver Spring, Maryland

Placing Reinforcing Bars, Concrete Reinforcing Steel Institute, Chicago, Illinois

Specifications for Ready-Mixed Concrete of the American Society of Testing and Materials, National Ready-Mixed Concrete Association, Silver Spring, Maryland

TEST

1. Complete the following statements:

   a. The three basic components of concrete are _____, _____ and _____.

   b. Concrete is usually reinforced with _____ _____.

   c. _____ is the commonly used material to bind concrete.

   d. The two general classes of aggregates are _____ and _____.

   e. A measure of the fine particles in fine aggregate materials is generally reported as the _____ _____.

   f. Materials which are added to concrete mixtures to produce certain characteristics are called _____.

   g. The _____ _____ is the standard material used for reinforcing structural concrete.

   h. The full rated strength of concrete is usually attained in _____ days.

2. What type of cement would be recommended for each of the following specific desired characteristics:

   a. high sulfate resistance? _____

   b. general construction use? _____

   c. low heat of hydration? _____

   d. high early strength? _____

3. Type I and Type II air entrained cements would be identified as _____ and _____.

Underline and correct the errors in the following materials handling and storage procedures in Questions 4 through 7.

4. Cement

   a. Bulk cement to be delivered in dump trucks.

   b. Unload into bins by gravity flow.

   c. May be intermixed with old cement stock.

   d. Sacked cement to be stored in sheltered area on pallets.

5. Aggregates

   a. Materials to be stockpiled in earthen pit.

   b. Materials to be piled on flat surface.

   c. Stockpiled material may be intermixed to reduce batching time.

   d. Truck traffic over stockpiled material improves the material gradation.

6. Admixtures

   a. Chemical admixtures may be stored in open tanks, in all seasons.

   b. Pozzolan storage should be in dry, closed vessels.

   c. Finely divided mineral admixtures are similar in appearance to fine aggregates, and clear identification is required.

7. Reinforcing Steel

   a. Deformed bars are stored on the ground.

   b. Bundles of 40' bars may be hoisted easily with a choker in the center during erection operations.

   c. For handling bundles of short bars, a bridle/choker rig may be used.

8. Describe how a purchaser can determine the acceptability of cements purchased to ASTM C150.

9. Describe the effects on concrete quality of foreign substances in aggregates.

10. Describe the effects on concrete quality by an excessively high water-cement ratio.

11. Describe the function of reinforcing steel including why it is deformed.

12. Name two chemical reactions which aggregates may cause and describe their effects on concrete quality.